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The Digital Decathlon - A Journey in Building Information Modelling Education

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ABSTRACT

The "Digital Decathlon" Erasmus+ project addresses the critical need for digital and green transitions in the Architecture, Engineering and Construction (AEC) sector by proposing an innovative approach for higher education. The project aims to prepare the next generation of professionals through a BIM-based design competition, designed as a novelty learning/gaming pathway for university students. By engaging participants from diverse countries and related academic backgrounds, the project fosters collaborative workflows and interdisciplinary teamwork by adopting a digital and gamified approach, providing hands-on learning and design experience. This paper presents the conceptual framework, methodologies and materials defining the prototypical learning format, which integrates online learning resources and tools, collaboration and mentoring, subject to a quality assessment for improvement and replication. Overall, the Digital Decathlon contributes to the advancement of educational methods necessary to address current challenges and to create the digitalised and sustainable built environment of tomorrow.

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1. Introduction

In the present era of urgent green transition, it is even more recognised that a parallel digital transition is necessary to cope with the complexity of sustainability challenges, demanding an acceleration in the development of new skills and competences, thereby an advancement in educational and training offerings. To address this requirement, Digital Decathlon is a 28-month project co-founded by the EU Erasmus+ programme coming with the slogan "build digital- build better". Merging academics from five European university departments in the AEC field, the underlying premise of the project is that the global demand for energy-efficient and decarbonised buildings can only be met by leveraging the untapped potential of digital technologies, particularly considering the game-changer BIM (Building Information Modelling). The project sets out with the ambitious goals of innovating BIM education by

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fostering digital knowledge, skills and competencies, while promoting more collaborative, interdisciplinary and intercultural ways of working. Inspired by the ancient Greek game format, Digital Decathlon is structured as a proper competition in which participant students must complete 10 disciplines to win, interpreted as BIM use-cases.

The paper contextualizes the current state-of-art in BIM implementation at EU level, both in the profession and education fields; then, the topic of BIM education inside the ERASMUS+ program is explored to underline the collective effort in finding new ways of teaching/learning; in this perspective, design competitions and novelty gamification approaches are introduced. Following, the contribution provides an overview of the project's methodology, detailing the format and the structure, the learning objectives, the design task and the competition requirements. The results of the first competition are analysed and discussed in terms of lessons learned, contributing to the optimization of the forthcoming second competition and the further improvement of the innovative learning format (Figure 1).

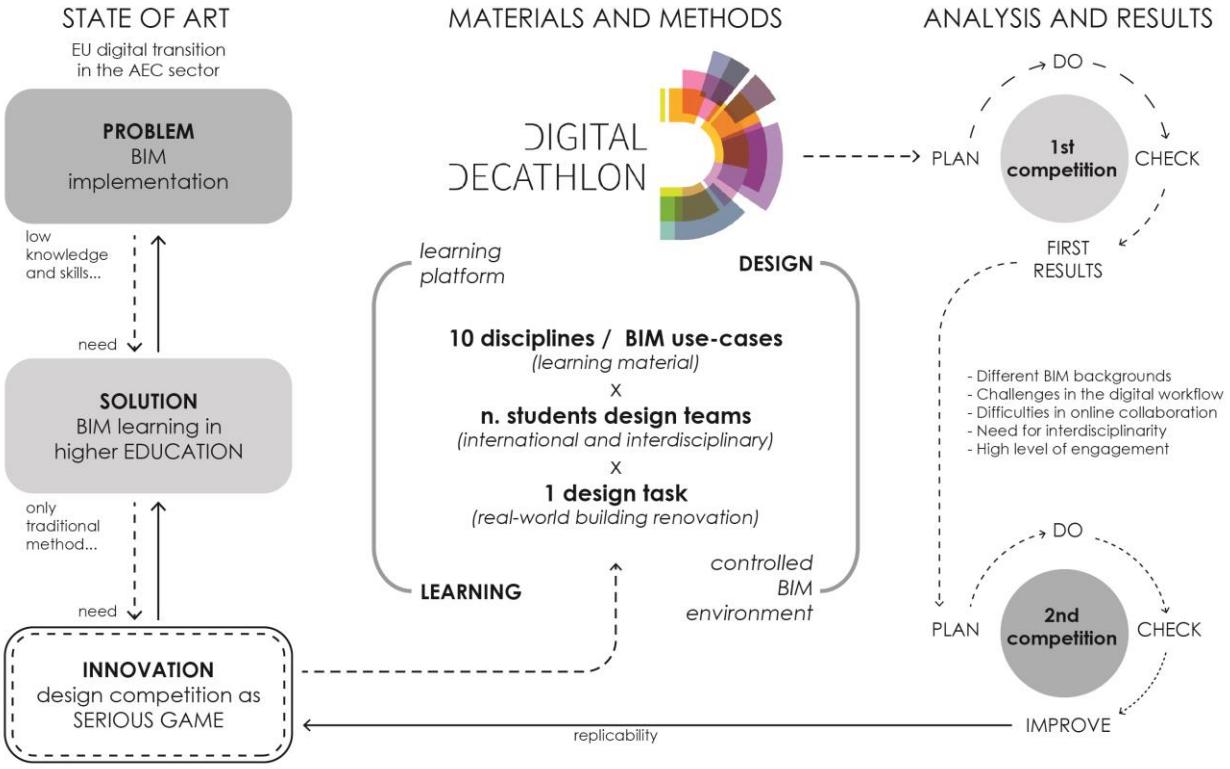

Figure 1. Structure of the study (developed by Author)

2. State of the art

Globally recognized as the most transformative and influential digital innovation in the AEC sector, BIM extends beyond traditional three-dimensional modelling by incorporating object-based semantic and relational databases, enabling a comprehensive collection, analysis, and sharing of data on technological components, properties, and performance, facilitating holistic lifecycle management and enhancing decision-making across the entire project lifecycle. Moreover, BIM is evolving in maturity, becoming a cornerstone within the ecosystem of Industry 4.0 technologies and beyond, including sensors, IoTs, augmented reality, robotics, drones, artificial intelligence applications and big data.

Although the development of BIM began several decades ago—dating back to the mid-1970s with the pioneering work of Charles Eastman (Eastman, 2011)—and despite its widespread global adoption, the formal integration into the EU regulatory framework only began with the European Directive 24/2014 on public procurement, which refers to "building information electronic modelling". According to Fiamma and Biagi (2023), this initial missed denomination has created a misunderstanding that still conditions clarity, speed and effectiveness in its adoption and diffusion, contributing to divergent implementation across EU member states. As national regulations increasingly mandate the use of BIM mandatory for public works projects, the sector remains largely unprepared, highlighting the urgent need for accelerated BIM education. If, on one hand, consistent up-skilling, training, and education are essential for fostering a common understanding, facilitating data exchange, and establishing standardized practices (Semaan et al., 2021), on the other hand, recognized barriers to BIM implementation include low levels of knowledge, resistance to cultural change, and a lack of awareness of its benefits (Charef et al., 2019). While technical training courses are proliferating to address the shortage of BIM skills, higher education institutions must reinforce their efforts on equipping future professionals with broader competencies, such as project management skills, to ensure comprehensive preparedness for the evolving demands of the AEC sector.

2.1. BIM education in Europe and the role of Erasmus+

From an AEC educational perspective, it is recognized that integrating ICTs such BIM enhances the acquisition of skills and spatial competences, serving not as mere graphical but as meaningful learning support, also boosting student motivation (Besné et al., 2021). However, an analysis of BIM courses across several European countries reveals that university offerings still largely rely on conventional teaching methods (Kępczyńska-Walczak, 2022 - BIMaHEAD project Erasmus+). The same study highlights the innovative potential of gamification approaches in this field. Moreover, considering the 20 years of experience in the US context, university BIM education should aim to increase, beyond knowledge, interdisciplinarity and collaboration among students (Morganti et al., 2022 – BENEDICT project Erasmus+).

The need to innovate AEC education in Europe towards digitalization and BIM can be found in the European Union's Erasmus+ flagship initiative for transnational cooperation and mobility in education, training, youth and sport. Launched in 1987 for higher education, the funding program enlarged in time, targets and numbers, reaching to this day more than 15 million people. Parallel to the growing interest in the AEC sector, the topic of BIM entered in more than seventy projects in the Erasmus+ financing period 2014-2020, with the majority of them falling under Key Action 2 - Cooperation for innovation and the exchange of good practices, and referring to higher education and vocational training. Key topics in these projects clearly describe the objectives and innovation needs in BIM education, with Erasmus+ addressing:

- Digital competencies in ICT-new technologies;
- New innovative curricula/educational methods;
- Open and distance learning;
- Environmental and climate change.

In the current funding program (2021-2027), seventeen projects are actually dealing with BIM education, mostly under KA2 (82%). Considering "cooperation partnerships in higher education" (KA220 HED), seven BIM-focusing Erasmus+ projects can be found, including Digital Decathlon, Bim4Energy, nZEBRA, BIM-LCA, GREENBIM, DIGILAB/BE and BIM4HEI. Looking at these projects, it is possible to observe not only the common need to still support the adoption of BIM in the higher education, but also the

reasons behind, that is the possibility to develop reliable and collaborative processes, and the capacity to perform simulations and analyses, such as energy performance and LCA calculations.

2.2. Innovative learning approaches: desgin competitions and serious games

Worldwide architectural competitions represent the best procedure when innovative projects have to be developed, particularly those requiring interdisciplinary expertise to address complex challenges such as environmental sustainability. While the tradition of competitions spans millennia, recent decades have seen a notable increase in competitions specifically targeting students. As testified by literature, this trend reflects their growing recognition as valuable didactic and educational tools, even more integrated into AEC academic curricula. Competitions offer a wide range of educational benefits, including "improving the ability to design, the ability to socialize through teamwork, and the ability to manage time" (Gunagama and Pratiwi, 2019, p. 6). Described as an "activating tool in architecture education" (Ilkovičová and Ilkovič, 2018), competitions provide students with practical and informal experiences that enhance their design skills.

Aligned with the mission of higher education institutions to prepare students for professional practice, competitions offer a unique opportunity to engage with real-world environments, apply theoretical knowledge to practical challenges, and simulate professional experiences. In this context, competitions can be viewed as a gamification tool for education, analogous to serious games. Designed not just for entertainment and exploiting digital technologies, serious games aim to educate by facilitating learning, training, health improvement, or raising awareness; they have already been adopted in architectural education (Goli et al., 2022). Design competitions in educational settings can be considered serious games based on the following shared characteristics:

- Educational Purpose: Aimed at developing knowledge and skills;
- Gamification Elements: Incorporating rules, guidelines, challenges, and rewards that engage and motivate students, encouraging active participation;
- Simulation of Professional Experience: Providing a controlled and realistic experience of professional life, combining creativity, technical proficiency, collaboration, time management, and project management. Competitions thus serve as essential tools for preparing students for the demands of the real-world work environment.

3. Materials and methods

To enhance learning and teaching methods in line with new digital requirements, the Digital Decathlon offers an innovative approach rooted in serious games. This method for BIM education was first piloted by the Digital Decathlon project leader, Jade University, in the BIM GAME project (Heins et al., 2021; Grunwald & Heins, 2022; Bhat et al., 2023).

The Digital Decathlon is structured as a design competition—a serious game for students in the interdisciplinary fields of architecture, civil engineering, and building services engineering. It immerses students in a BIM environment to collaboratively develop integrated design projects, challenging them to navigate 10 gaming disciplines or BIM use cases (Figure 2 and Table 1).

As a professional design competition, the Digital Decathlon includes key elements such as a real-world context, a design task, a timeline, briefs and guidelines, defined roles and regulations, minimal requirements, assessment criteria, a jury, and a reward system. To familiarize students with real BIM practice, Warsaw University prepared an Exchange Information Requirements (EIR) document, which clearly defines the scope of BIM technology application in the competition. In response, students are required to develop a BIM Execution Plan (BEP). Reflecting the EU's Renovation Wave priorities, the design task for the first competition centred on the requalification of an existing building.

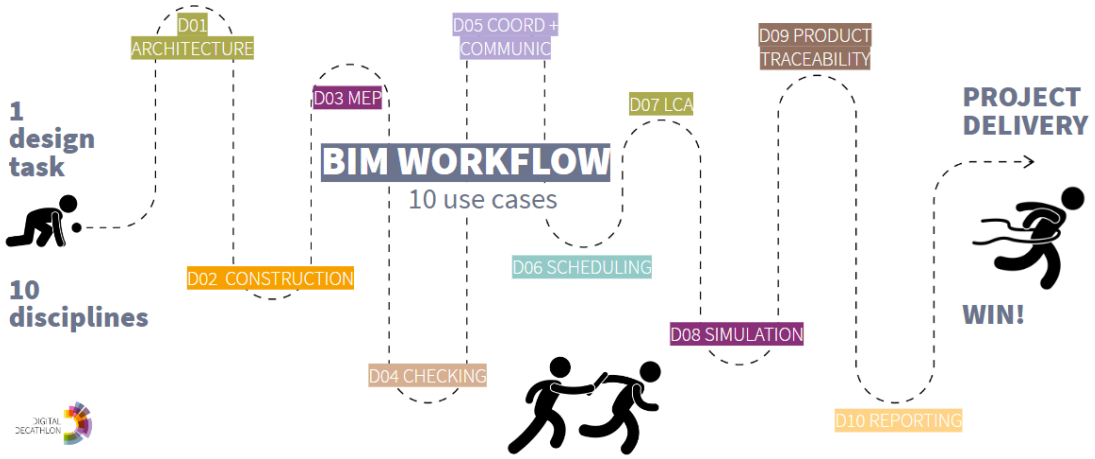

Figure 2. The Digital Decathlon competition across the 10 disciplines/BIM uses (developed by Author)

Table 1. DIGITAL DECATHLON disciplines/BIM uses and corresponding specific learning objectives

n.	Discipline	Specific Learning Objectives
1	ARCHITECTURE	Develop a design idea/spatial programme in a 3D model, with corresponding visualizations
2	CONSTRUCTION	Define and verify a wooden structure
3	MEP (Mechanical, Electrical and Plumbing)	Integrate MEP systems
4	MODEL CHECKING	Test the quality of models
5	DESIGN COORDINATION and COMMUNICATION	Coordinate models
6	CONSTRUCTION SCHEDULING	Visualize construction phase
7	LIFE CYCLE ASSESSMENT	Calculate LCA
8	SIMULATION	Perform energy and solar simulations
9	BUILDING PRODUCT TRACEABILITY	Organize building products' documentation
10	REPORTING	Communicate work in progress and results

For each discipline, dedicated digital learning materials were developed and delivered to students as engaging "click tutorials" on a specialized learning platform—Moodle (developed by Karelia University), which also provided online support tools. Additionally, to align initial BIM competencies, a pre-qualification online BIM basics course (developed by the University of Wuppertal) was offered and completed by all participating bachelor's students. In parallel, and simulating real-world conditions, a controlled Common Data Environment was established to allow students to experience BIM-based collaborative working.

To optimize the gaming format and ensure a high-quality learning experience, the project employs a methodology based on quality cycles (plan, do, check, and improve) with two planned competition/learning cycles. The first competition has already concluded, and the second is currently being prepared, leveraging the insights and results from the first cycle for continuous improvement.

4. Analysis and Results

The design task was introduced to students during the opening event held in Wuppertal, Germany, in October 2023. To provide students with an immersive experience of the project site and context, the launch of the first competition took place at the Wuppertal Solar Decathlon 2021-22 (solardecathlon.eu) (Figure 3), a renowned location featuring full-scale prototypes of future sustainable houses still functioning as Living Labs. At this venue, twenty-five students from five partner universities, organized into five interdisciplinary and international teams (Figure 4), gathered for the first time and began the concept design phase collaboratively.

Figure 3. Launch of the first competition in Wuppertal (by Christian Heins)

Working in interdisciplinary and international teams, students engaged in strategic co-planning of the BIM process. They selected two disciplines each, based on their academic background, competencies, and learning interests, and organized their online collaboration accordingly.

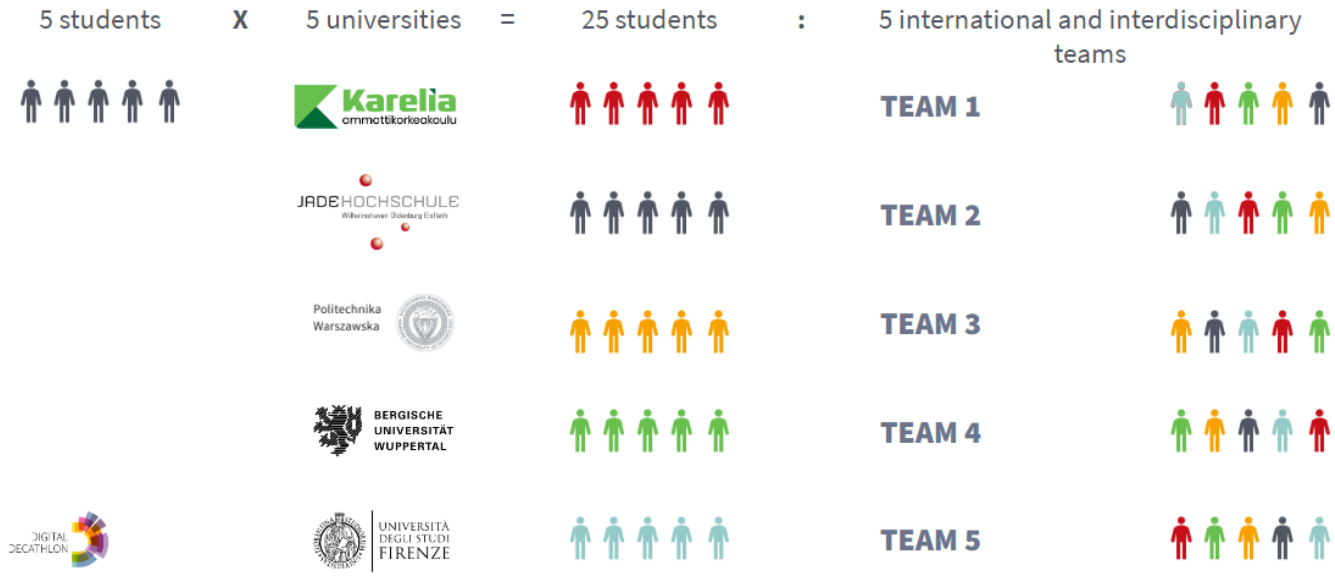

Figure 4. Composition of the student teams (developed by Author)

The design task required students to repurpose an abandoned former logistics center into a multi-purpose cultural centre, contributing to the ongoing regeneration of a former industrial area and transforming it into a vibrant neighbourhood with diverse social and cultural activities.

Students were provided with detailed instructions on the content and organization of learning materials for the ten disciplines and the competition itself. A BIM asset model of the building was also delivered. With all learning materials available online through Moodle and a clear ten-step design task, student teams worked autonomously and remotely to develop their project proposals. A mid-term review was conducted to assess progress.

The design proposals were developed in an interdisciplinary manner, leveraging the collaborative capabilities of the controlled BIM environment. Students enhanced the sustainability of their designs through simulations (e.g., energy consumption) and detailed analyses (e.g., LCA). Additionally, trainers offered on-demand coaching sessions via videoconference to address specific issues. After four months of remote teamwork, each student team submitted their BIM materials in the Common Data Environment (CDE), along with two representative A1 posters (Figure 5) and a multimedia presentation.

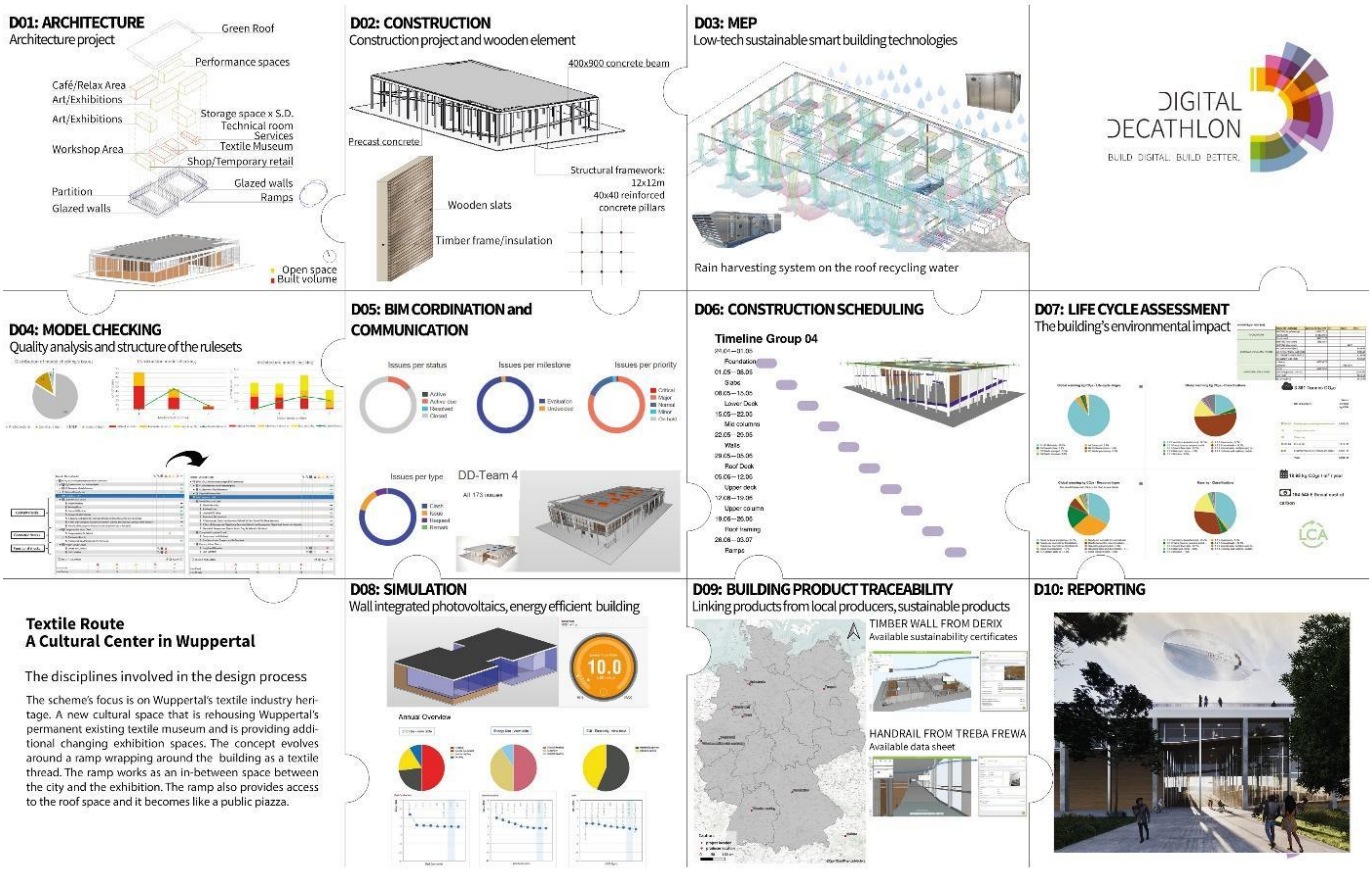

Figure 5. Winner project's poster (students: A. Antoniadou, A. Stuenkel, C. Girod, M. F. Perri, P. Wojnar)

The winners were announced at the final event held at the University of Florence in February 2024. During this event, student teams presented their approaches to the BIM process across the ten disciplines/BIM uses and demonstrated how these approaches supported their design solutions. The final jury consisted of the project team of trainers and external BIM experts. The evaluation was based on weighted assessment criteria (Table 1) aligned with the learning objectives, ensuring a coherent and fair assessment process.

In addition to evaluating the technical outcomes of the integrated design proposals, the first competition provided initial insights into the challenges and opportunities of innovating BIM education through a competition-based, gamified approach. Key findings include:

- Diverse BIM backgrounds: despite targeting students with similar academic backgrounds, varying levels of prior BIM experience were evident;
- Digital workflow challenges: the array of software, plug-ins, and data management systems in the BIM environment was a novelty for the mayority of students, necessitating dedicated technical support;
- Online collaboration difficulties: relying solely on remote working sessions led to a decline in team enthusiasm;

- Need for interdisciplinarity: students had limited experience collaborating with peers from different disciplines;
- High engagement: while students were eager to learn, the added human, social, and intercultural value of the experience was highly appreciated.

These insights highlight both the benefits and areas for improvement in using a competition-based and gamified approach to BIM education.

5. Discussion

Echoing the uneven implementation of BIM in the professional realm, the study revealed a varied level of BIM background among students, including challenges in managing the digital ecosystem. Additionally, students displayed limited experience in interdisciplinary design—a critical component for developing truly sustainable projects, which BIM can facilitate. This underscores the need for higher education systems to enhance and innovate learning methods to better prepare students for the digital demands of professional work. Furthermore, the exclusive use of online modalities presents challenges, highlighting the need for improved gamification features.

Despite these challenges, the Digital Decathlon observed a positive student attitude towards learning, reflecting a strong recognition of the importance of digitalization and the benefits of participating in an international competition with an intercultural social dimension.

Aligning with theories on experiential learning and serious games, the project's primary hypothesis was that engaging students in a structured, interdisciplinary competition simulating real-world professional challenges would foster critical BIM skills, collaborative competencies, and a deeper understanding of sustainable building practices.

The insights gained from the first competition's strengths and weaknesses have identified crucial areas for improvement to optimize the upcoming second competition. The project demonstrated that serious games and competition-based learning can effectively enhance digital skills and competencies, supporting the hypothesis that gamification can improve learning outcomes. The iterative learning cycles and feedback mechanisms embedded in the project provided students with valuable opportunities for reflection and continuous improvement, essential for deep learning.

6. Conclusion

This study investigated the potential of a gamified, competition-based approach to BIM education, using the Digital Decathlon project as a case study. The primary issue addressed was bridging the gap between traditional BIM education and the evolving demands of the construction industry, particularly the integration of digital competencies. The research tackled these challenges effectively by implementing a structured competition that engaged students in a realistic, collaborative BIM environment. Early results suggest that the innovative Digital Decathlon format successfully fosters critical BIM skills and enhances students' understanding of sustainable building practices, thus achieving the research objectives.

The study's key contribution is its innovative approach to BIM education, demonstrating that serious games and competition-based learning can significantly improve digital literacy and interdisciplinary collaboration among students. This approach is effective in preparing students for the complexities of contemporary construction projects and addressing sustainability challenges. Additionally, the study emphasizes the value of incorporating social and intercultural dimensions into technical education, extending beyond mere skill acquisition.

However, the study has limitations. The format is still in its initial prototypical phase with a limited number of participants. Variations in students' prior BIM experience suggest that further refinement is needed to

ensure consistent learning outcomes. Future phases of the project will explore strategies to standardize initial BIM skills, facilitating smoother and more successful development of integrated projects. Subsequent iterations of the Digital Decathlon should address these limitations to ensure that the model can be scaled and replicated globally.

Despite these challenges, the study highlights the importance of advancing educational models to better address deficiencies in students' digital backgrounds and improve the integration of digital tools in learning and design processes. Further research is needed to develop more comprehensive and standardized BIM education across higher education institutions, ensuring students are well-prepared for sustainable projects.

Although in its early stages, the Digital Decathlon is providing significant contributions in BIM education by enhancing not only technical skills but also human and social soft skills, valuing the importance of collaborative, international, intercultural, and interdisciplinary learning experience.

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The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

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